ABSORPTION OF CARBON DIOXIDE FROM GAS MIXTURES UNDER PRESSURE

BY

AARON PASHKOW

ARMOUR INSTITUTE OF TECHNOLOGY

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Absorption of Carbon Dioxide from Gas Mixtures Under Pressure

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A THESIS

PRESENTED BY

AARON PASHKOW

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APPROVED:

H. McCormack
Professor of Chemical Engineering

H. M. Raymond
Dean of Engineering Studies

L. C. Monin
Dean of Cultural Studies

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INTRODUCTION.

Due to the sudden decrease in the manufacture of intoxicating liquors and subsequent increase in the manufacture of non-intoxicating beverages there was created a shortage in the production of carbon dioxide.

It was then suggested by Professor Harry McCormack that the senior class design a carbon dioxide plant as a part of the course of Industrial Chemistry.

It was found that the cheapest method of preparation is the burning of coke and subsequent absorption of the carbon dioxide from the resulting gaseous mixture. It was also found that the greatest waste in the production of carbon dioxide occurred in the process of absorption of the gas.

The literature available described the process of absorption from gaseous mixtures (Containing 18% of CO_2) under atmospheric pressure as inefficient and recommended absorption under pressure as more efficient, though no effort has been made

to prove the fact. Various patents for the absorption of carbon dioxide from gaseous mixtures under pressure are registered but with the exception of the SUERTH and SURTHER processes none of them were tried on a commercial scale.

It was with the view of investigating the absorption of carbon dioxide from gaseous mixtures under pressure, that the author set out to determine the factors for its successful application to industry from a scientific standpoint.

I wish to express my thanks to Professor H. McCormack for his suggestions and direction of my work.

Chicago, Illinois. May 1 9 2 1.

PROCESSES OF MANUFACTURE OF CARBON DIOXIDE.

Before discussing the absorption of carbon dioxide it is advisable for a better understanding of the same to describe the most efficient methods for the manufacture of carbon dioxide.

This can be best accomplished by tracing drawing No. 1, in which "A" represents a boiler in the furnace of which material such as coke is treated. The products of this furnace are composed mainly by carbon dioxide, nitrogen and what may be considered impurities. The mixture of gases passes through pipe "A" into a scrubber "B", which is filled with coke or the like and sprayed with water. The object of this scrubber is to remove from the furnace gases the coarser and cruder impurities; from the scrubber "B" the preliminary washed gases are passed to the chemical purifier "C". The scrubber "C" is also filled with coke, and is sprayed with a chemical solution adapted to remove from the furnace gases all deleterious gases still remaining in the furnace

gas. A chemical solution suitable for this purpose consists of bicarbonate of soda or potash. From the chemical purifier "C" the gas is carried through the pipe "C" to the compressor "D". In this part of the apparatus the gases are composed of carbon dioxide and nitrogen, with perhaps a small addition of carbon monoxide and oxygen. All of these gases except carbon dioxide pass through the absorbers without undergoing any chemical action and are deleterious in the use of the process. The gases leave the compressor "D" under a pressure of four to five atmospheres, and enter absorber "F" through pipe "E". Care must be taken to have valve "E" closed so that all the gases leaving the compressor will pass through absorber "F". This absorber will extract most of the CO_2 by meeting a counter current of potassium carbonate solution. The saturated potassium bicarbonate settles to the bottom and the unabsorbed gases continue their travel through absorber "G", the gases still being under pressure. The remaining unabsorbed gases can either be

passed through a third absorber or passed from the pipe line "E" through connection "J" and to engine "K". This engine may be utilized in the plant for any other purpose. The gases are then released from the system through exhaust "L".

The potassium bicarbonate which has collected at the bottom of the absorber "F" is taken to generator "M" which is heated by exhaust steam from compressor "D", which transmits the solution through exhaust pipe d' into coil d^2. This heating action in the generator "M" liberates the carbon dioxide from the bicarbonate solution, leaving the carbonate solution free for use over again in the system. The waste heat of the carbon dioxide liberated in the generator "M" is utilized by passing the carbon dioxide through the pipe "M" into the heating jacket of the engine "K" after which it passes through a cooler "N" and into the gasometer "O" from which it is drawn and liquefied in the usual manner or utilized directly in the manufacture of commercial products. The importance of utilizing the heat of the

carbon dioxide in the steam jacket of the engine "K" resides in the fact that it prevents the freezing up of the exhaust pipe "L" by the moisture of the waste gases which has a tendency to solidify because of the release of pressure at this point. The heat of the carbon dioxide also expands the gases entering engine "K" through pipe "F" and therefore increases the motive power efficiency of the gases.

The heat of the rejuvenated lye leaving the generator "M" is further utilized by the following means. It passes through a pump "P" driven by belt K' from the engine "K". This pump "P" forces it into the heat exchanger system RS, R'S'. This heat exchanger system comprises a series of double pipes; one side of the other, the hot potassium carbonate solution passing in one direction and the cold potassium bicarbonate solution in the other. The heat is cooled as it passes the pipe "R" (THE OUTSIDE OF THE DOUBLE PIPES IN THE ILLUSTRATION BUT IN PRACTICE IT IS PREFERABLY REVERSED) and when sufficiently cooled passes up the pipe R' into

APPARATUS FOR INDUSTRIAL PREPARATION OF CO_2

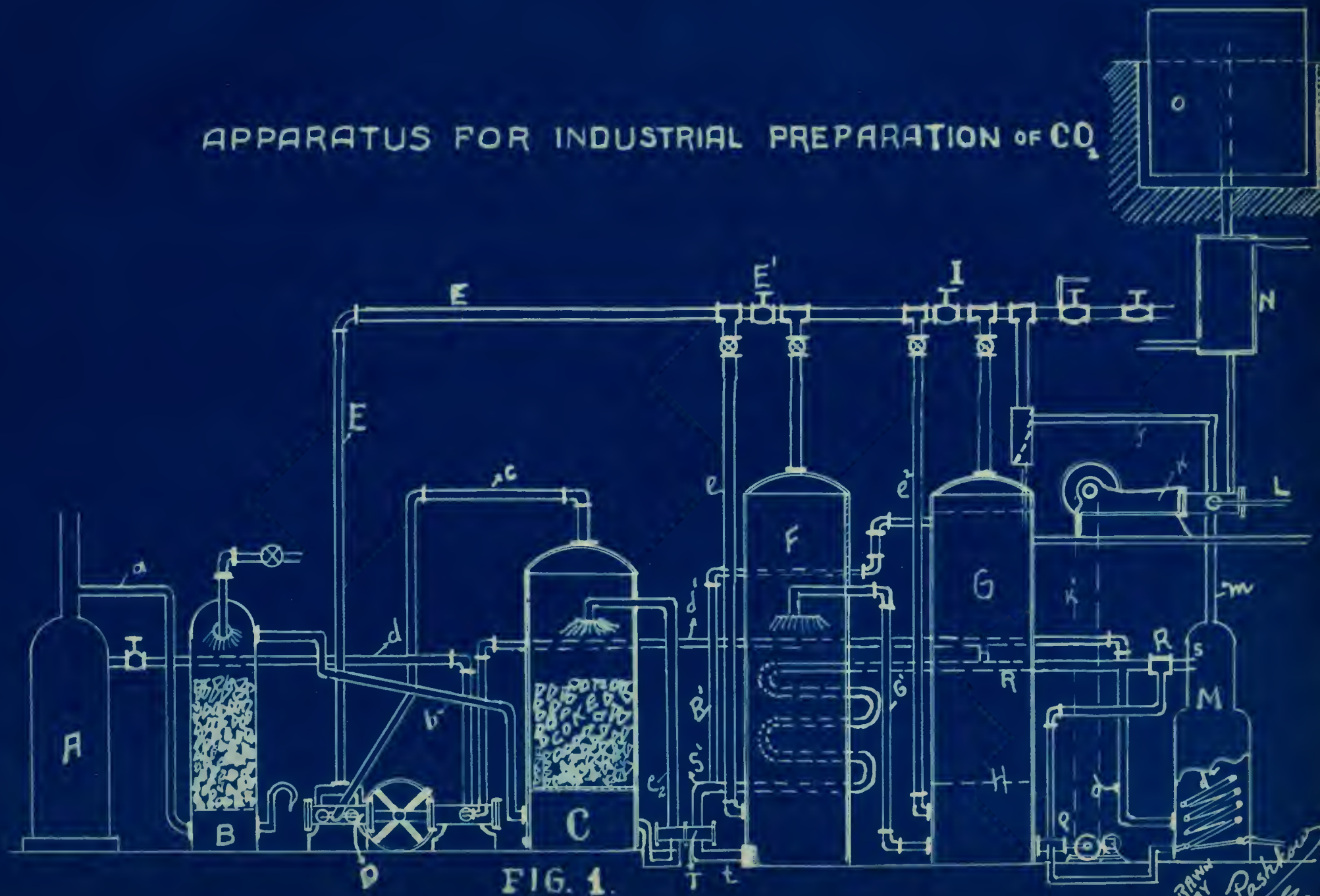

FIG. 1.

DRAWN BY A. Pashkin

the upper part of the absorber "G". The bicarbonate which is heated by the heat exchange apparatus empties through the pipe "S" into the generator "M". It is brought to this point by being withdrawn from the bottom of the absorber "F" through the pipe "t" into the pump "T" from which it passes through the pipe "S" through the double heat exchange system.

As the bicarbonate solution in the absorber "F" is under considerable pressure, this pressure will force the bicarbonate solution through system tT, SS'. The excess pressure is utilized to drive the pump "T" the object of which is to circulate the chemical solution in the purifier "C" by means of circularing pipe "C^2"

The process described resembles the SURTHER PROCESS which is used to a great extent in Germany.

"The Naamlooze Vernootschap-Ant. Jurgens Vereinigde Fabriken" use instead of potassium carbonate an alkali solution in which magnesium hydroxide and basic magnesium carbonate is suspended.

Behrens in his patent recommends the use of

calcium carbonate and interpetes the reaction as

$$CaCO_3 + H_2O \rightleftarrows Ca(OH)_2 + CO_2$$

the reaction going more to the right the higher the decomposition temperature. He suggests the use of a closed vessel at temperature of 150 degrees and pressure of 4 to 5 atmospheres.

The problem of conservation of heat in the plant is one which is worth while studying for the engineer who intends to produce carbon dioxide most economically. A good discussion of the utilization of heat in a carbon dioxide plant is given in the Chem. and Met. Eng. Vol. 9 (158).

ABSORPTION.

HISTORY:

The first important work on the subject of absorption was done by HENRY[1], who expressed the results of his investigations as follows:

"The total quantity of gas absorbed is always proportional to the pressure of the gas." BUNSEN[2] and his students confirmed Henry's law in their work on the same subject. With the invention of more delicate instruments a series of investigations have been conducted by Von Bohr and BOCK[3], L. WINKLER[4], TIMOFEJEW[5], SETCHENOW[6], JUST[7]. However, on the sobject of absorption of gases under pressure in different solutions not much work was done with the exception of the investigations of CHANIKOFF, LUGININ[8], S.WROBLEWSKI[9], LEONARDO CASUTTO[10], and WILHELM SANDER.[11]

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1. Phil. Trans. 1803, Gilb. Ann. 20, 147
2. Lieb. Ann. 93, 1(10). Gasometric methods
3. Wied. Ann. 44, (318).
4. Zeit. fur Physikal. Chemie 9, (171).
5. " " " " 6, (141).
6. Mem. Ac. Petersburg 22, 6.
7. Zeit. for Physik. Chemie 37, 342.
8. Ann. CHIM. Phys. 4, 412.
9. WIED. Ann. 17, (103, 18 (290).
10. Nuovo Cimento 6, (1903).
11. Zeit. PHYS. CHEMIE 78, (513).

Chanikoff and Luginin investigated the absorption of carbon dioxide in water up to a pressure of 4 atmospheres. Wroblewski continued these experiments up to a pressure of sixty atmospheres, and in the investigations he found the substance $CO_2 \cdot 8H_2O$ at 0 degrees. Casutto experimented with different gases to a pressure of ten atmospheres.

All these investigations led to the conclusion that gases do not behave according to Henry's Law, from which it was to expect that under increased pressures the absorption will become greater in proportion to the pressure notwithstanding the nature of the solution. It was then observed that carbon dioxide is absorbed faster at one pressure and slower at another. This was especially noted when applied to a mixture of gases. It was found that each gaseous component in a mixture of gases is absorbed in proportion to its partial pressure as was pointed out by Dalton.

MECHANICAL AND CHEMICAL INFLUENCES UPON ABSORPTION.

In the factories where carbon dioxide is the

main product the absorption, is of great importance. Under most efficient combustion the per cent of carbon dioxide in the gases of the process described is not above 18%, of which less than 50% are absorbed. The loss is due partly to chemical and partly to mechanical faults in the process.

Mechanical influence.

To some extent the loss is due to mechanical inefficiencies of the apparatus and for this purpose different kinds of absorption apparati have been designed, however, none of them completely eliminate the loss. A fine layer of lye, spread over a large surface affords the best opportunity for absorption.

The simplest absorber is the mixer type Fig. 3, which is used in mineral water factories for carbonating purposes. It consists of a cylinder with a shaft extending through same. Fastened to this shaft are a number of perforated paddle wheels. A simple stuffing box closes the cylinder at each end around the shaft. The lye as well as the gas connections to the cylinder is made at opposite points, which forces the lye and

gas to travel in opposite directions to their respective outlets. The paddle wheels take up very nearly the whole diameter of the cylinder, with only a small clearance at either end, so that a thorough mixture of gas and lye is obtained. As many absorbers of this construction as may be required are connected in series, and the connections are so made that lye and gas travel in opposite directions from absorber to absorber until the outlet is reached. This arrangement requires the employment of force pumps for both gas and lye.

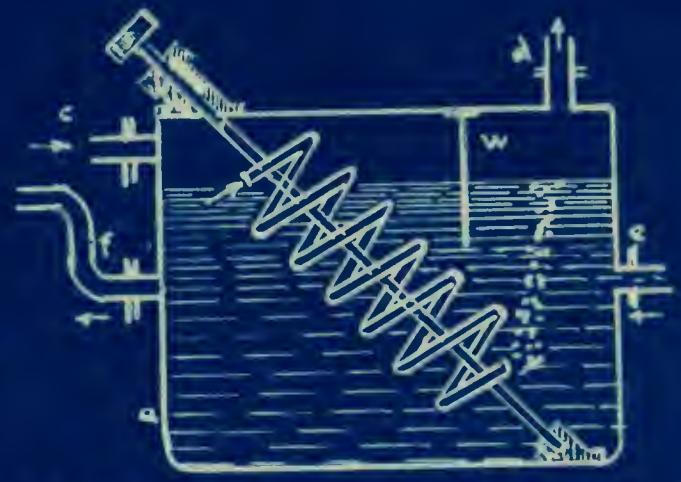
An improved absorber which is used to some extent is provided with a revolving spiral coil as shown in Fig. 4. The coil is placed within the receptacle, "a", in a diagonal position; both ends are open and as the receptacle is filled with two thirds of its height, the balance of the space being occupied by the gas, the upper end of the spiral takes at each revolution first a small quantity of gas and on its turn through the lye a portion of the latter, thereby inclosing the

gas with the coil and forcing same to travel through the coil and out at the outlet "s", from whence it is forced to bubble through the body of the lye into the space "w" which latter is divided from the gas by a partition. On its way through the spiral coil lye and gas are thoroughly mixed, and the balance of the carbon dioxide is absorbed from the gas when same passes through the body of lye "fresh" entering the inlet, "e". The saturated lye passes out at "f", while the fresh gas enters at "c"; outlet "D", disposes of the remnants of the gas and leads same to the next absorber. The spiral coil revolves at a speed of not less than 100 revolutions per minute.

The mechanical sprayer, used sometimes, consists of a closed receptacle provided with a paddle wheel. T he lye reaches a height just sufficient to enable the spoon-shaped paddles to dip into same, take up a small quantity of lye at each revolution and throw same with considerable force through the upper part of the receptacle which is filled with the gas. The velocity of the

SIMPLE ABSORBER

FIG. 3.



ABSORBER WITH REVOLVING COIL

FIG. 4.

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A. Pashkow

paddles must be sufficiently high to keep up a continual rain of lye through the gas, each drop absorbing a fractional amount of carbon dioxide.

Force sprinklers are used. These usually consist of an upright cylinder containing the gas at a slight pressure. The sprinkler is at the bottom. A small stream of lye is forced into the sprinkler which scatters the lye so that the latter shoots through the gas space in small drops. Each drop again absorbs whatever carbon dioxide it can on its flight through space and the saturated lye is carried off at the bottom.

Revolving wire sieves, the next apparatus, are mounted on a revolving vertical shaft; these divide the gas into very fine bubbles, while the lye passes through the cylinder in a solid body, entering at the top and leaving same at the bottom. The gas enters at the bottom and each mesh of the revolving wire sieve carries with it a bubble of gas, disposing of same by means of a centrifugal force. Provision is made to carry the gas back to the center between

each section of sieves, so that the gas is divided into small bubbles time and again until it finally passes out at the top. On account of the weight of the column it is necessary to force the gas through same by means of a blower.

Absorption towers of different sizes and construction have been tried but they do not prove to be very efficient. Dr. E. Luhman's design for tower absorption is the one giving the most satisfactory results.

Many additional constructions have been tried to improve the efficiency of absorption towers. Among others is the converting of the absorbing solution into a foam by means of revolving sieves, for the purpose of increasing the surface of the lye. The practical gain is offset by the increased mechanical complication of the absorber and by the increase in power required to revolve the sieves.

Above all these methods stands the method of absorption under pressure, the advantage being that of increased efficiency. The tower must however be built stronger and the gas entered

under pressure.

Chemical influence.

When two different gases are mixed if there is no chemical reaction between the gaseous particles, it has been found that each gas conducts itself as though the other gas was not present. In fact all the physical properties, such as pressure exerted on the walls of the containing vessel, the specific heat, etc., experience no change. Hence if we have a mixture of gases in contact with a liquid each individual gaseous species exerts its own individual pressure and according to Henry's Law the amount of this particular gas absorbed should be proportional to this pressure. In fact, it has been shown by Dalton (1807) that the solubility of a gas is unaffected by the presence of other gases and that the amount of each absorbed is proportional to its own partial pressure.

In the case of the carbon dioxide in a mixture containing 18% at atmospheric pressure

the partial pressure of the carbon dioxide would be .18 of an atmosphere; in a gaseous mixture under pressure of 4 atmospheres, on the other hand, the partial pressure of the carbon dioxide becomes 4 times .18 that is .72 and thus the absorption is greatly increased compared with absorption at ordinary pressure.

On the other hand in working at atmospheric pressure, as in the other processes, if 15% carbon dioxide is absorbed by a 7% potassium carbonate solution in the first absorption tower, gas containing 8% carbon dioxide will still be present in the second tower, the absorbed quantity will diminish rapidly because the partial pressure of the carbon dioxide decreased from .15 to .08 of an atmosphere and the absorption in a third tower is rarely attempted. This explains how a considerable portion of the carbon dioxide produced in the coke furnaces is lost in the old process and why it is not absorbed by two or three potash towers.

Owing to the fact that the products of combustion from which the carbon dioxide is to be absorbed, are mixed with large volumes of indifferent gases, it is not possible to convert the potassium carbonate in the lye into a full bicarbonate. In most cases only the one and one-half stage of a carbonate is reached unless the gases are exceptionally rich in carbon dioxide as for instance in kiln gases. Nor is it possible to reconvert the one and one-half carbonate into a simple carbonate during the boiling process unless the solution is boiled a long time, which is not economical. It is not a simple carbonate when it enters the absorption tower and not a full bicarbonate when it leaves it, which explains the low efficiency of absorption.

The reaction that takes place in the absorber may be expressed as follows:

$$K_2CO_3 + CO_2 + H_2O \rightleftarrows 2KHCO_3$$

The reaction taking place under pressure results in the increase of absorption of the

carbon dioxide, 75% of which is released upon reducing the pressure. The remaining absorbed gases are liberated by heat.

EXPERIMENTAL WORK.

A. The problem of thesis investigation:

From the theoretic study of absorption it was concluded that in order to determine the best condition of absorption the three factors involved (pressure, temperature, and concentration) should be investigated. The following plan was proposed:

VARY	KEEP CONSTANT
Concentration	Temperature & Pressure
Pressure	Concentration & Temper.
Temperature	Concentration & Pressure

The variation of temperature at constant pressure and concentration could not be obtained due to the limited means and lack of time. It was also intended to use different absorbents but time did not permit the execution of the intentions.

B. Apparatus:

Not being able to obtain hot furnace gases rich in carbon dioxide, it was decided to obtain carbon dioxide from a cylinder and mix it

with air. The carbon dioxide was absorbed from this mixture. Being mostly interested in the absorption of carbon dioxide the problem of purification of the gas was not given any attention. The apparatus consisted mainly of the absorbing and liberating units. The liberating unit aiding in the exact determination of absorbed gases.

The apparatus Fig. 2 consisted of an absorber "A" with one opening at the bottom "1", one at the side near the bottom "2" and two at the top "3" and "4". The absorber was divided into compartments by perforated wooden plates boiled in hot paraffine, so as to prevent their destruction during the test. The plates were dried and as such fit into the absorber, making any escape of gas except through the perforated plates impossible. The space between the plates was filled with coke so as to offer more resistance and surface to the passage of the gases. The absorber in the laboratory was of small size and it was found that the gas

passes through the plates in a very short time, but with addition of coke better results were obtained. This proved the fact that a large absorbing surface is a necessity for good absorption. The carbon dioxide was obtained from a gas cylinder "B" and on its way to the absorber it passed a pressure regulator "C". The pressure regulator was installed because it was found difficult to obtain the desired pressure at the entrance of the gas into the absorber. The gauge "D" was constantly changing until the pressure regulator "C" was attached. It was then possible to obtain any pressure and keep it constant until the end of the test.

Upon leaving the pressure gauge regulator the gas passed a part of the pipe with a venturi effect. This served in drawing air into the pipe. The carbon dioxide being mixed with the air entered as a mixture into the absorber. This mixture was tested and the % of carbon dioxide determined.

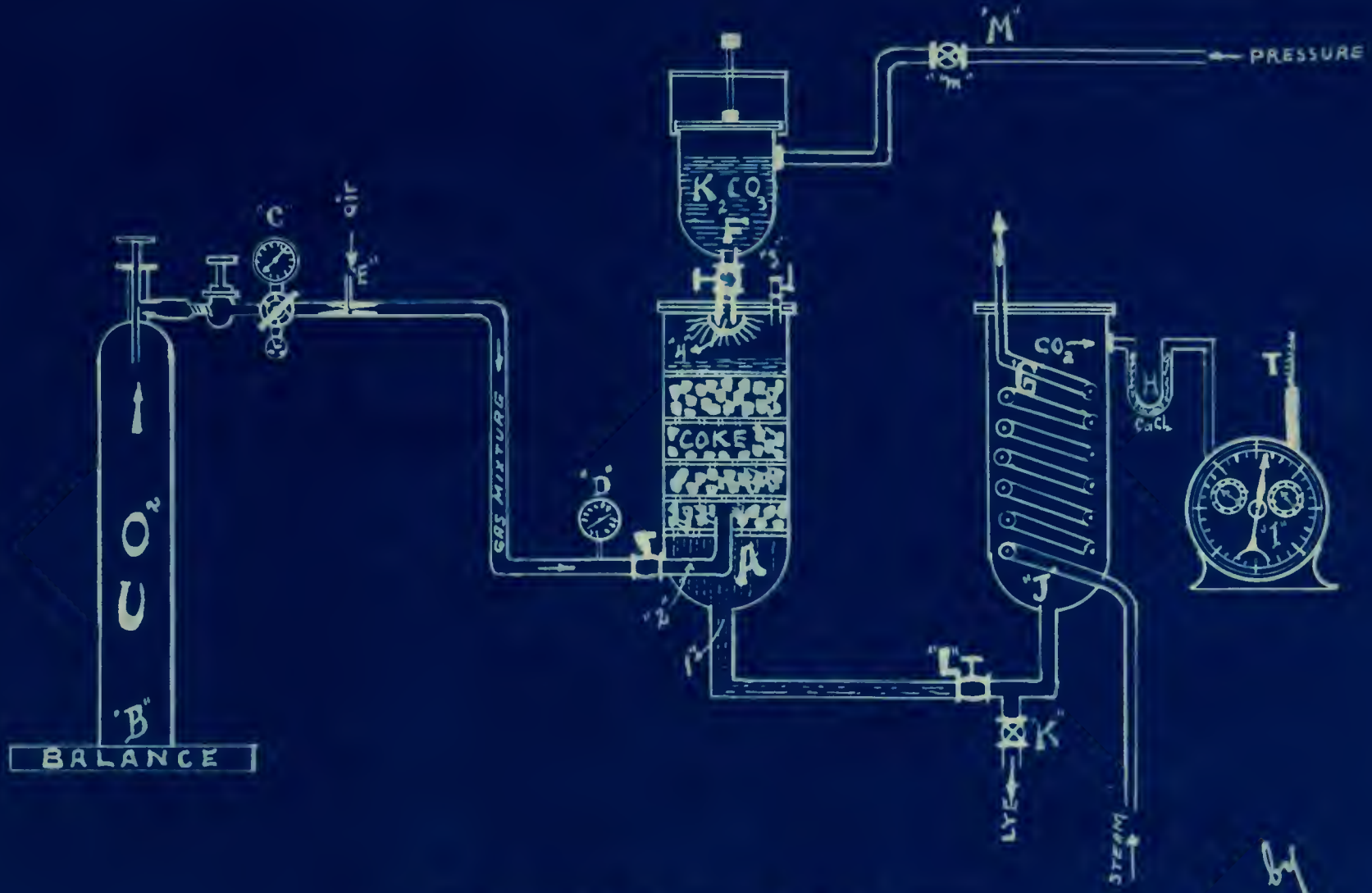
The gas passing the perforated plates was

met by a counter current of absorbing solution (potassium carbonate). The solution entered through the opening "4" regulated by a valve so as not to get empty before the test is over. The solution was under pressure from line "M", the valve "m" making it possible to obtain any pressure desired.

The unabsorbed gases were evolved through opening "3". The unabsorbed gases were tested and contained from 1 to 6% CO_2, varying with the concentration, temperature and pressure.

The bicarbonate solution was transferred from absorber "A" to the liberating unit "G" by opening valve "L" and closing valve "K". The liberating unit "G" consisted of a container provided with steam coils "J". The steam was to aid in the release of 50% of the carbon dioxide. As was the case with these tests it only released about 25% of the carbon dioxide, since 75% was released by reduction in pressure.

Having released all the carbon dioxide the carbonate solution was emptied into a vessel



LABORATORY APPARATUS

FIG. 2.

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by having valve "L" closed and "K" opened. The solution was then ready for use in the next absorption.

The solution was transferred from the absorbing unit by the liberating unit by means of the pressure of the liquid through opening "4", care being taken that no air was transferred.

The gas leaving the liberating unit passed through the drying tube "U" into the gas meter. The amount of gas liberated was registered in cubic feet. The cylinder "B" was weighed before each test.

C. Calibration of the pressure gauge.

The absorption depending upon the pressure it was thought necessary to calibrate the pressure gauge of the absorber.

The gauge to be tested was connected with a gauge tester and the stop-cock connecting the gauge with an oil chamber was opened; the plunger was screwed in until the piston and platform have risen two or three inches above

its lowest position. The readings of the gauge (under test), together with actual readings, in pounds, as registered by weights of the gauge tester were recorded. The pressure then increased by 5 pounds and corresponding readings recorded. The error was very large. The needle was then removed by the needle-jack and reset at a pressure of ten pounds. After several adjustments of the gauge the errors were eliminated.

D. Procedure:

Solutions of different concentrations of potassium carbonate were prepared. Concentrations of 15, 20, 25, 30 degrees Beaumé were considered sufficient to obtain the necessary results. The volume of each solution was calculated so as to have enough carbonate in the solution to absorb all the liberated gas. An addition of 25% was used so that no loss could be charged to the inefficiency of absorption of the potassium carbonate. The calculation was done on the basis of 3 pounds of carbon

dioxide being absorbed by one cubic foot of potassium carbonate of 20 degrees Beaumé (12.3 lbs. of potassium carbonate being contained in one cu. ft. at 20 degrees Beaumé.)

The solution was placed in the container "F" Fig. 2 and the gas passed into the solution under different pressure. The pressure, concentration, and temperature were regulated as planned. The solution was then transferred to container "J" where the carbon dioxide was released partly by roduction of pressure and partly by heat. The per cent of absorption was then:

$$\frac{\text{amount released from B} \times 100}{\text{amount (lbs.) passed thru meter}}$$

VARYING PRESSURES AT 75 DEG. F. & 30 DEG. Bé.

PRESSURE	CO_2 TAKEN	CO_2 ABSORBED	% ABSORBED.
		RUN NO. 1 Curve 1 A.	
0	1	.195	19.5
10	.875	.363	41.5
20	1	.534	53.4
30	.937	.564	60.1
40	1	.634	63.4
50	1	.65	65.0
		RUN NO. 2.	
0	.875	.175	20.5
10	1.165	.478	42.5
20	.875	.459	53.5
30	.875	.528	60.4
40	1	.632	63.2
50	.937	.605	64.5
		RUN NO. 3	
0	1.063	.216	20.0
10	.415	.174	42.0
20	.937	.516	55.1
30	1	.595	59.5
40	.937	.598	63.5
50	.875	.569	65.0

Pressure	0	10	20	30	40	50
Average % Absorb.	20	42	54	60	63.5	65.0

VARYING PRESSURES AT 95 DEG. F. & 25 DEG. BÉ.

PRESSURE	CO_2 TAKEN	CO_2 ABSORBED	% ABSORBED
	RUN NO. 1	Curve 1 B.	
0	.875	.138	15.8
10	.937	.322	34.4
20	1.165	.512	44.0
30	.875	.445	50.9
40	1.063	.578	54.4
50	1.165	.65	55.8
	RUN NO. 2.		
0	1.165	.186	16.0
10	1.063	.368	34.6
20	1.063	.466	43.9
30	1.165	.593	50.9
40	.937	.51	54.5
50	1.063	.596	56.1
	RUN NO. 3.		
0	.937	.149	15.9
10	.875	.302	34.5
20	.937	.414	44.1
30	1.063	.545	51.2
40	.875	.476	54.6
50	.937	.526	56.0

Pressure	0	10	20	30	40	50
Average % Absorb.	15.9	34.5	44	51	54.5	56

VARYING PRESSURES AT 110 DEG. F. & 20 DEG. BÉ.

PRESSURE	CO_2 TAKEN	CO_2 ABSORBED	% ABSORBED.
		RUN NO. 1 CURVE 1 C.	
0	1	.142	14.2
10	1.165	.333	28.6
20	.937	.352	37.6
30	.875	.384	43.9
40	1	.466	46.6
50	1.165	.565	48.5
		RUN NO. 2	
0	.937	.134	14.3
10	1.063	.301	28.5
20	.875	.328	37.5
30	.937	.412	44.0
40	1.063	.493	46.4
50	1.063	.515	48.5
		RUN No. 3.	
0	.875	.123	14.1
10	1	.284	28.4
20	1	.374	37.4
30	1.165	.51	43.8
40	1.165	.541	46.5
50	1	.485	48.5

Pressure	0	10	20	30	40	50
Average % Absorb.	14.2	28.5	37	43.9	46.5	48.5

VARYING PRESSURES AT 120 DEG. F. & 15 DEG. BÉ.

PRESSURE	CO_2 TAKEN	CO_2 ABSORBED	% ABSORBED.
		RUN NO. 1	Curve 1 D.
0	.937	.112	12.0
10	.875	.209	23.9
20	1.165	.38	32.6
30	1.063	.40	37.6
40	.875	.363	41.5
50	1	.421	42.1
		RUN NO. 2.	
0	1	.12	12.0
10	.937	.226	24.1
20	1.063	.345	32.5
30	.937	.353	37.7
40	.937	.388	41.4
50	.875	.418	41.9
		RUN NO. 3.	
0	.875	.105	12.0
10	1	.24	24.0
20	1	.324	32.5
30	.875	.328	37.5
40	.937	.416	41.6
50	1	.419	41.9

Pressure	0	10	20	30	40	50
Average % Absorb.	12	24	32.5	37.6	41.5	42

VARYING CONCENTRATIONS AT 75 DEG. F & 50# PRESSURE.

CONCENT. BE'	CO_2 TAKEN	CO_2 ABSORBED	% ABSORBED
	RUN NO. 1		Curve 2 A.
15	1	.459	45.9
20	1.165	.629	54.0
25	.937	.554	59.0
30	1.165	.76	65.2
	RUN NO. 2.		
15	.937	.439	45.8
20	1	.541	54.1
25	.875	.515	58.9
30	1.063	.694	65.2
	RUN NO. 3.		
15	.875	.40	45.7
20	.875	.471	53.9
25	1	.591	59.1
30	.937	.611	65.2

Concentration	15	20	25	30
Average % Absorb.	45.8	54	59	65.2

Carbon dioxide in mixtures 25%

Carbon dioxide liberated 99.8% pure

VARYING CONCENT. AT 95 DEG. F. & 40# PRSSSURE

CONCENT. BE'	CO_2 TAKEN	CO_2 ABSORBED	% ABSORB.
	RUN NO. 1		Curve 2 B.
15	.937	.399	42.6
20	1	.496	49.6
25	1.165	.639	54.9
30	.937	.564	60.2
	RUN NO. 2.		
15	.875	.371	42.2
20	.875	.434	49.6
25	1.063	.584	54.8
30	.875	.527	60.3
	RUN No. 3.		
15	1	.425	42.5
20	.937	.465	49.6
25	1	.547	54.7
30	1	.601	60.1

Concentration	15	20	25	30
Average % Absorb.	35.4	42	48.5	53.8

VARYING CONCENT. AT 110 DEG. F.& 30# PRESSURE.

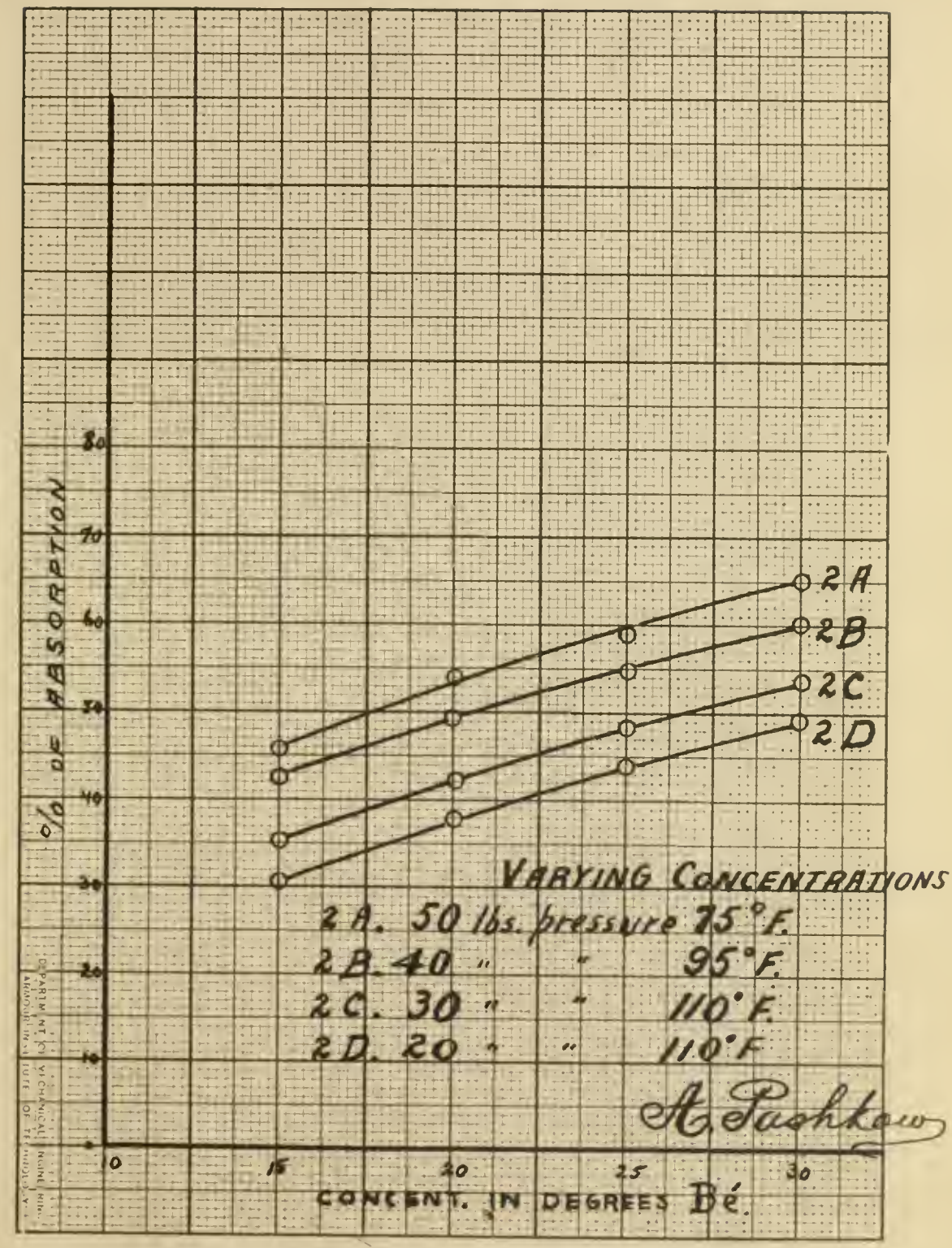
CONCENT. BE'	CO_2 TAKEN	CO_2 ABSORBED	% ABSORBED
	RUN NO. 1		Curve 2 C.
15	.875	.267	30.5
20	1.165	.442	37.9
25	.875	.383	43.7
30	1.0	.491	49.1
	RUN NO. 2.		
15	1	.308	30.8
20	1	.379	37.9
25	.937	.412	43.8
30	1.063	.521	49.0
	RUN NO. 3.		
15	1.165	.356	30.5
20	1	.379	37.9
25	.875	.383	43.9
30	1.063	.521	48.9

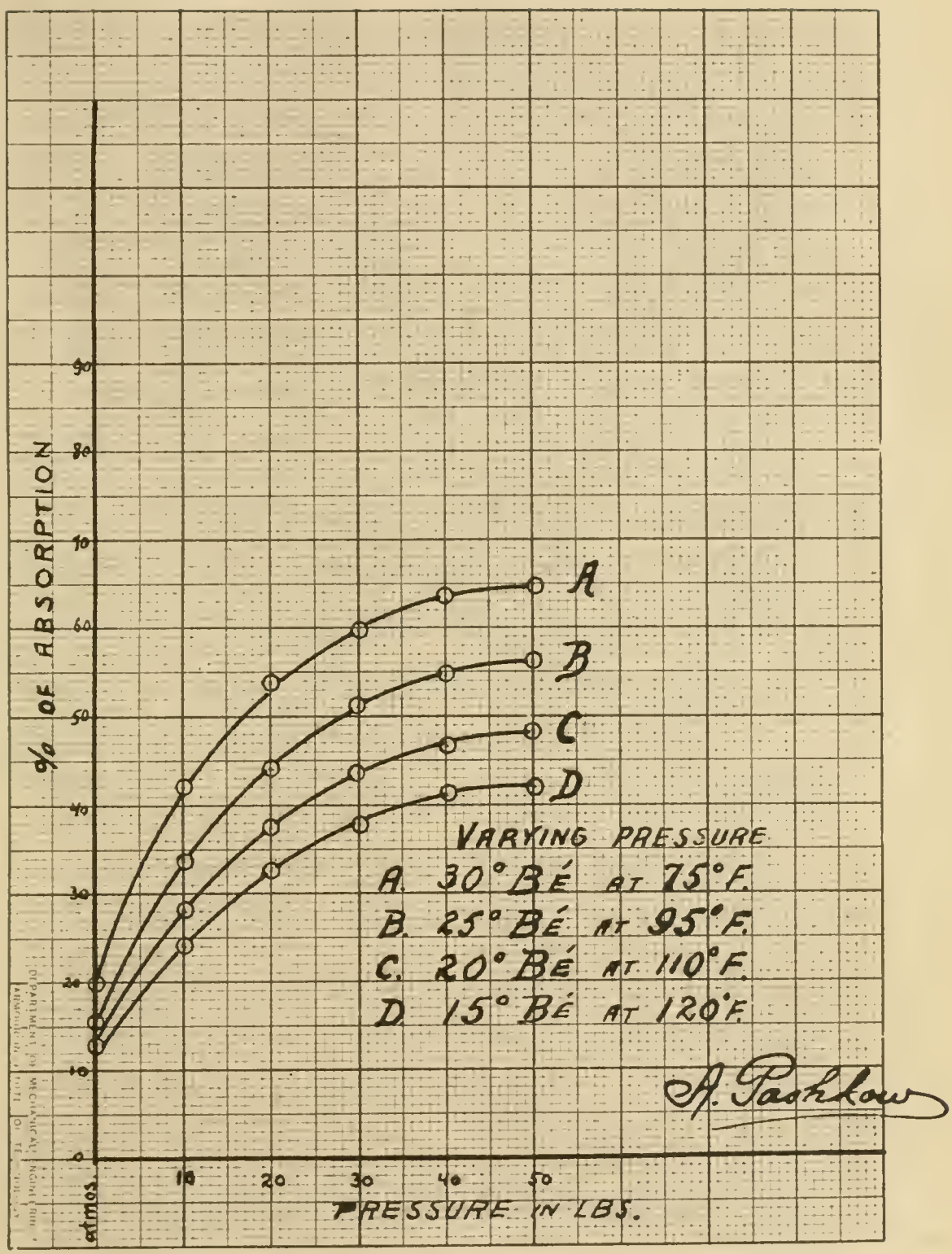
Concentration	15	20	25	30
Average % Absorb.	30.6	37.9	43.8	49.0

VARYING CONCENT. AT 110 DEG. F. & 20# PRESSURE.

CONCENT. BÉ.	CO_2 TAKEN	CO_2 ABSORBED	% ABSORBED.
	RUN No. 1.		Curve 2 D.
15	1	.353	35.3
20	.875	.368	42.0
25	1.165	.566	48.8
30	.875	.471	53.8
	RUN NO. 2.		
15	.937	.332	35.4
20	.937	.394	42.0
25	1.063	.516	48.5
30	.937	.505	53.9
	RUN NO. 3.		
15	1.063	.378	35.5
20	1	.42	42.0
25	1	.484	48.4
30	1	.537	53.7

Concentration	15	20	25	30
Average % Absorb.	35.4	42	48.5	53.8


% OF ABSORPTION
80
70
60
50
40
30
20
10
0
10
15
20
25
30
CONCENT. IN DEGREES Bé.
2A
2B
2C
2D
VARYING CONCENTRATIONS
2A. 50 lbs. pressure 75°F.
2B. 40 " " 95°F.
2C. 30 " " 110°F.
2D. 20 " " 110°F
A. Pashkow
DEPARTMENT OF MECHANICAL ENGINEERING
MASSACHUSETTS INSTITUTE OF TECHNOLOGY


% OF ABSORPTION
90
80
70
60
50
40
30
20
10
0
atmos.
10
20
30
40
50
PRESSURE IN LBS.
A
B
C
D
VARYING PRESSURE
A. 30° BÉ AT 75° F.
B. 25° BÉ AT 95° F.
C. 20° BÉ AT 110° F.
D. 15° BÉ AT 120° F.
A. Pashkow

DISCUSSION OF RESULTS.

From a study of the results obtained it can be concluded that the process of absorbing carbon dioxide from gaseous mixtures under pressure is one that should be used commercially in the manufacture of carbon dioxide.

The per cent of absorption gradually increases with higher pressure, greater concentration and lower temperature. At a concentration of 15 deg. Bé. the absorption, under a pressure varying from atmospheric to 50 pounds, increases from 12 to 40%. With gradual increase in concentration the gain is still larger.

That the concentration has a decided effect on the increase in per cent of absorption is shown by test 2A., where the pressure and temperature were kept constant and concentrations varied. The result showed that with an increase from 15 to 30 degrees Beaumé the absorption increased 14%.

The highest efficiency of absorption was obtained under the highest pressure and concen-

tration and at the lowest temperature. The effect of a varying temperature during the process of absorption could not be obtained, but the absorptions performed at different temperatures, all other factors being the same, proved that high temperatures of the absorbing solutions decrease the per cent of absorption. The highest efficiency obtained with the laboratory apparatus described was 65%. Due to lack of time the apparatus could not be improved upon so as to obtain a still better absorption, but it is conceivable that a larger efficiency can be obtained by improving the mechanical means of absorption.

If we let X equal pressure of CO_2 in the gas entering the absorption system.

X' equal pressure of CO_2 in waste gases

Y equal CO_2 tension of exhausted lye solution

Y' equal CO_2 tension of carbonated lye.

We can obtain the most favorable conditions for recovering the CO_2 from the lye solution when Y' is a maximum and Y is a minumum. X will normally

have its greatest value when the percentage of CO_2 in the gases approaches 20 and Y will have its lowest value the more completely the lye is boiled and the lower the temperature at which absorption is commenced. The highest efficiency will be obtained when X equal Y': and X' equal Y. This can be obtained when sufficient time is allowed for absorption and when the amount of carbonate present is exactly adjusted to the amount of CO_2 available.

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J. C. GOOSMAN

THE CARBONIC ACID INDUSTRY.

DR. H. LUHMAN

KOLENSAURE

C. KAUSH

KOLENSAURE

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W. C. LEWIS

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